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Problem

Since the late 1970's there has been a lot of research to identify students' conceptions about physics (e.g., Pfundt & Duit, 1999). Now, more recent studies attempt to identify the factors that support the evolution of students' initial knowledge towards scientific knowledge. Among the studies of conceptual change (Posner, Strike, Hewson & Gertzog, 1982), we belong to small group of researchers that follow learning and change processes in real time, that is, "the data is collected continuously during the learning process. The aim is to capture and be able to describe the entire process" (Niedderer, 1992). To follow learning and change processes, we need to model the students' thought and use the definition: "knowledge" is a set of ideas, (which could be contradictory between themselves or not), each one can be applied in several material situation, these situations represent the domain of validity of one idea (Balacheff, 1999). We reconstruct a student's ideas on the basis of his/her actions, especially, verbal productions, communicative gestures, and manipulations of experiences.

In this paper, we document how students' ideas evolve in a teaching sequence, specifically designed with the aim of understanding how students learn. The ultimate goal was to improve the teaching of gases at the level of higher secondary school (10 grader, 15-16 year old). Our general research question was, “How do the student's ideas evolve in our teaching sequence on gases?” To follow the student's conceptualization, we will focus on the role of communicative gestures, especially on the synchronization between speech and gesture (Roth, 1999).

Background

Communicative gestures have been classified into different types including those of deictic (pointing), iconic, metaphorical, and beat nature (Kendon, 1985; McNeil, 1992; Scherer, 1984.). Deictic gestures "point" out some aspect of the context. Iconic gestures and the entities they stand for are characterized by mapping relationships such that both be understood in terms of the same topological features. For an example, a scientist might outline a graph by following it using her finger, and thereby highlights the shape of its line. In a similar way, metaphorical gestures provide a visual expression of a metaphor, even though the concept or idea may be abstract. Finally symbolic gestures function as independent signs and obtain their sense through shared social conventions (raising of middle finger to signal an obscenity) (Roth 1999). In this study, we will focus only on iconic and metaphoric gestures, especially their synchronization with speech, because together, speech and gesture constitute a good indicator of knowledge (Goldin-Meadow, 1997).

Our general methodology for reconstructing student's ideas is based on the following theoretical framework. Vygotsky (1985) considers that the study of language could give us access to how people think. But students’ discourse is not simply a "window on the mind", but a "dirty window", because the language used and produced depends on context (Edwards, 1993). We used the French concept of *contexte pertinent* (relevant, salient context; Kerbrat-Orecchioni, 1996) to define the context. Relevant context included the following elements: time of student's actions, task (the question that the students are doing in the sequence on gas), and description of the different actions that the students are doing: talking, reading, writing, handling. Furthermore communication has to be understood as occurring in multiple channels at once (Lemke, 1998) and as being interpretively flexible (many possibilities of sense). We

therefore transcribed the verbal productions, communicative gestures, and manipulating gestures.

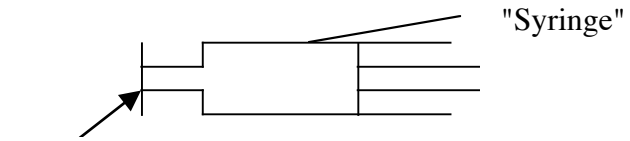
Procedure

In this study, an intensive in-depth case study approach was selected. Eight fifteen-year old French students were followed during a teaching sequence on gases, which had been designed by a team including teachers and researchers (this sequence could be downloaded on the site pegase http://nte-serveur.univ-lyon1.fr/pegase/). The design is based on a socio-constructivist approach with respect to three main dimensions.

1- The modelling activity (Tiberghien, 2000): students establish links between the world of objects/events and that one of theory/model favours students' learning.
2- The semiotic registers (Duval, 1995): students represent the same concept in various semiotic registers (natural language, diagrams, graphs...) and establishing relations between these registers favours students' learning (e.g., force).
3- The students' conceptions of gases (Benson, 1993; Méheut & Chomat, 1990; Séré, 1985; Stavy, 1988): students construct new knowledge from initial knowledge.

Studying the evolution of student's ideas in a fine-grained manner involves analysing the students' learning processes during a real teaching sequence. We therefore filmed the eight students continuously and collected their written productions—there were three experimental sessions of 1h 30 and three working sessions of 1h. On the whole, the video corpus duration is 8 hours and the written production consists of 10 pages per student approximately.

Example of transcription with the elements of context (Table 1):

Time	*Activity*	*Description*	*Transcription*
Question 1. Enclose air in a syringe. Draw a diagram			
00:06:14:16	Act1 Q1	A explains to E, that it must close the entry of the syringe	
00:06:28:00		A explains to E, and A does the experiment	A: if you only do that (A closes the syringe with her finger) here you're enclosing air into/ do you agree (?) E: yes A: when you pull out/ after/ (A closes the syringe and pulls out the piston) it's just a question of pressure/ I think and you see here/ the quantity is more important
Written production of student A:  "we close with the finger to enclose air"			

Data Analyses and Findings.

The analysis of our data video show how synchronization between gestures and speech could be a pertinent indicatory of student's conceptualization. Gestures are interpretively flexible

and the same gesture can be used to refer to different entities and have therefore different sense. This sense depends on context. For example, the closing of the hand (Figure 1) in itself does not “mean”; it is together with speech and context that the topic of communication is established.

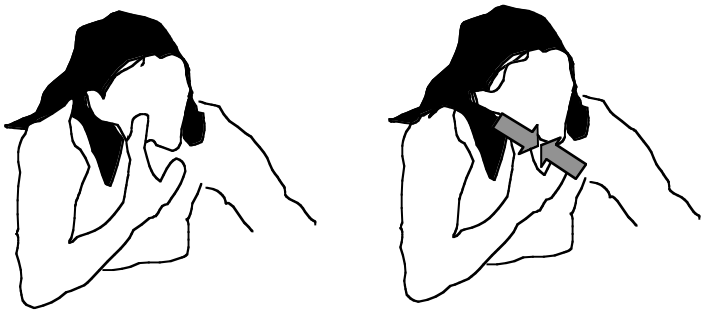


Figure 1: Gesture of bringing together her finger

We give an example of this gesture in a different context during the second working session (1h). In this session students are working in small group of four persons.

The first example concerns the measure of pressure in a syringe when the student was decreasing the volume of the syringe. In this extract, student A explains the question to another student M. It is the beginning of the working session (Time = 10:53 m)

01 A: and after it's when we push <u>when we ma- when we make smaller the volume</u> (gesture of bringing together her finger)
02 M: when we make smaller (M is mocking of A's pronunciation)
03 A: when we decrease the volume

In line 1, student A is searching for words and finally she uses the verb "rappetissir" (make smaller). In this case gesture and speech occurred simultaneously. We hypothesize that student A use this gesture because it allows her to specify the sense of the word. And this hypothesis should be confirm by the following fact: when she employed the correct physics word "decrease" (line 3), she did not employ a concurrent gesture. Afterwards, she never used gestures again when uttering sentences involving the "decrease of volume".

The second example involves the description of actions of a gas in the syringe while the student was decreasing the volume of the syringe. This example is during the middle of the working session (Time = 31:36 m). In this small extract, student A and E are talking about the behavior of molecules.

01 E: what are you writing?
02 A: that the that the (gesture of bringing together her finger)
03 Student A uses the same gesture to do a description of the molecules behavior. But in this case, she has not specifics words. Afterwards, she searches a word to describe this phenomenon.

This research of good word is illustrating by the last extract (Time = 32:57 m):
01 A: What are you saying to me they (molecules) are doing what?
02 M: they are clashing

03 A: no but before/ I don't like this word
04 M: ah but I don't know
05 A: they (molecules) are what (gesture of bringing together her finger)
06 M: compensate
07 A: n::::o (gesture of bringing together her finger)
08 Ad: they are hitting (laughing)
09 A: you know they are doing something together (gesture of bringing together her finger)/ but no they don't hit
10 M: they are rebounding (laughing)
11 A: but no they are (gesture of bringing together her finger)

This extract shows that student A had developed an idea about molecules behavior but she did not have a word to describe. She used only the same metaphoric gestures.

These tree examples illustrate how synchronization between gesture and speech is a good criterion for establishing a student's current conceptualizations :

- When a gesture appears before speech (example 2 & 3), we a student is at the beginning of the conceptualization. Because he/she has an idea about the phenomenon but he/she hasn't any word to express it.
- When gesture and speech are simultaneous (example 1), the meaning of the word is not enough precise and gesture should be like a kind of "complement" of meaning.
- When speech is used without a gesture (example 1), we consider that meaning of word has overtake some stability.

Our data illustrate the fact that the same gesture should be have different meaning and associate to different concepts (volume (example 1) and molecules (example 2 & 3)).

Contribution.

In the past, research on conceptions and conceptual change has relied solely on students' utterances to specify their knowledge and understanding. This study shows the significant contribution to the specification of conceptions and conceptual change that are made by the study of gestures. This study allowed us to specify criteria for following the evolution of students' learning and development with respect to their conceptual knowledge.

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